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Guide to the Geology of the Upper Schuylkill Valley

By

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GUIDE TO THE GEOLOGY OF THE UPPER SCHUYLKILL VALLEY

By BRADFORD WILLARD

INTRODUCTION

The Pennsylvania Topographic and Geologic Survey is engaged in publishing guidebooks to the geology of several localities of particular interest in the State. Some of these guides are based upon the annual trips of the Field Conference of Pennsylvania Geologists, others are derived from a series of educational field trips in geology which the Survey has sponsored since 1935. The present excursion is based upon one of the latter which started at Pottsville and ran south to Hamburg. However, in the revised form, that trip has been amplified along the route north of Hamburg, and has been prolonged southward to embrace the section at West Leesport. One of the educational trips was held at Reading, and (Bulletin G 15) a guidebook to the geology about that city can be purchased from the Bureau of Publications at Harrisburg. This book will tie in with the southern end of the present account.

The section is located partly in Schuylkill County, partly in Berks County. It extends along the Schuylkill Valley, following, save for a few short side trips, U. S. Highway 122 between Pottsville and Leesport. The entire section is contained on the Pottsville, Hamburg and Reading topographic sheets of the United States Geological Survey.

PHYSIOGRAPHY

The route followed in the itinerary for this bulletin traverses regions of quite dissimilar physiography. The northern part from Pottsville south through the Schuylkill water gap above Hamburg crosses a portion of the Ridge and Valley Section of the Appalachian Valley Province. This is an area characterized by parallel or concentrically curved, alternating ridges and valleys. South of this lies the Appalachian Valley Section of the same Province. This is crossed from Schuylkill gap southward to the southern end of the trip north of Reading, from which point it is possible to see, in the distance, hills belonging to the Appalachian Mountain Province. These are the highlands near Reading, known as the Reading Prong.

To an observer of the mountain ridges to the north, it is at once apparent that their tops are approximately level, and that the several ridges rise to somewhat near the same elevation. This phenomenon is

Photograph by Bradford Willard

Figure 1—View north from Schuylkill Gap toward Port Clinton. The Schuylkill cuts across the ridges.

attributed to their being more or less reduced remnants of an ancient land surface which has been dissected and cut away until the only parts left are these even-crested ridges. Between them and parallel to them are longitudinal valleys, but, crossing at right angles to the ridges, that is, "across the grain" of the country, is the deep, transverse valley of the Schuylkill. Into it the tributary streams run more or less at right angles along the lateral, intermontane valleys. The resulting stream pattern is called trellis drainage.

If one examines the rocks which form the ridges and underlie the longitudinal valleys between the ridges, he will observe with respect to erosion that the former are hard, resistant, the latter soft, non-resistant, perhaps soluble. Furthermore, the bedding of most of these rocks is tilted up on end or at least at high angles to the horizontal, although we know that originally these layers of rock were essentially flat-lying. Evidently, at some time in the past, the rocky strata were squeezed and folded, broken and up-tilted, to produce such disturbed conditions. Following upon an interval of bending and breaking, stream erosion is believed to have worn the entire surface down low and nearly flat, or, using the technical term, to a peneplane. Such a surface conceals beneath itself the folded, distorted strata, which, because of their differences in hardness, are potential mountains and valleys. Suppose the entire peneplane should be raised and again subjected to erosion, what might happen? Simply, the hard beds would be etched out as mountain ridges, the soft, deeply excavated to form intermontane valleys. Assuming at the same time that the ancestral Schuylkill flowed across this uplifted peneplane in essentially its present course, being a powerful river (the master stream of the area), it would have been able to disregard the varying hardness or resistance to erosion of the rock bands, and to cut its course deeply down, transverse to the trend of the rocky bands. Thus the Schuylkill

Photograph by Bradford Willard

Figure 2—View north from near Shoemakersville. Martinsburg shale hills in foreground, Kittatinny Mountain and Schuylkill Gap in distance.

today has a transmontane valley. The weaker, tributary streams, unable to cut down through the resistant layers, have adapted their courses to the bands of soft rock. Cutting these down, the hard bands were left standing, and our present ridge and valley type of topography resulted.

As the rocks of the Reading Prong are both hard and resistant, they too have stood up as a peneplane remnant. Between these and the southernmost Kittatinny Mountain ridge, stretches the Appalachian Valley. Floored by soft shales and soluble limestones in general, no rocks were present capable of producing more than small, local ridges. The whole surface eroded at nearly the same rate, and resulted in the subdued, rolling territory of today with its crooked, meandering streams, and low hills.

Photograph by Geo. H. Ashley

Figure 3—View east from near Hawk Mountain. Rolling Martinsburg shale topography with Shochary Ridge in middle distance.

STRATIGRAPHY

All of the rocks in the section from Pottsville to Leesport are of *sedimentary origin,* as contrasted to *igneous* and *metamorphic,* although some have been so squeezed that they are on the borderline with the last named group. Igneous rocks like lava have cooled from a melted state; metamorphics are derived from other rocks by changes commonly brought about by heat and pressure. Sedimentary rocks are mostly made up of particles of older rock which have been broken up, worn away, transported to new locations, and re-deposited. Principally this is by the action of water. Some of them, such as salt, gypsum and limestone, may be precipitated from solution. The rest, such common forms as shale, sandstone and conglomerate, composed of particles of indurated mud, hardened sand and cemented pebbles, respectively, are called clastic rocks and are of the fragmentary nature alluded to just now. Sedimentary rocks usually are found in layers called *beds* or *strata.* Of the sedimentary rocks in this area, most were deposited in the sea, but some are of fresh-water origin. This is known from the kinds of fossils which they contain. *Fossils* are remains of animals and plants which were buried in the sediments before they hardened. As living forms today are characteristic of the places in which they dwell, so fossils indicate the sort of environment which existed about them when they were flesh and blood or waving green fronds.

In many of the rocks we may discover fossil shells and other parts of animals which once dwelt in the ocean, for they resemble those which we today see along the seashore. Other rocks, however, instead of containing the remains of sea shells, carry plant fragments such as leaves, stems or trunks, and the tracks of four-footed, land-going animals. Such strata, we naturally presume, must have been produced on land. The following table attempts to summarize in compact and easily accessible form the sequence of formations to be seen in the area described in this guidebook.

GEOLOGIC TIME TABLE

	Thickness Feet
PENNSYLVANIAN SYSTEM	
Coal Measures, about Pottsville. At the base is the coarse *Pottsville conglomerate.* It forms Sharp Mountain south of Pottsville	1,000+
MISSISSIPPIAN SYSTEM	
Mauch Chunk formation. Red sandstone and red shale in the valley between Sharp and Second Mountains	2,000±
Pocono formation. Gray sandstone and conglomerate with occasional bands of black shale verging upon coal; plant fossils present. This formation underlies the northern crest of Second Mountain	1,000

	Thickness Feet
DEVONIAN SYSTEM	
Catskill facies. Dominantly red sandstone and shale separated by non-red members. Such an one is the *Honesdale sandstone.* This rock is very like the Pocono. It forms the southern crest of Second Mountain. In the valley between the two crests of this mountain, and separating the Pocono from the Honesdale are red beds of the higher part of the Catskill. Additional red strata occur south of Second Mountain. The few known fossils are of plants and fishes	3,000+
Portage group. Dominated by the greenish-gray, flaggy *Trimmers Rock sandstone.* Marine fossils common. The Trimmers Rock grades into the red Catskill facies which is of fresh-water or land origin. Beneath the thick Trimmers Rock sandstone are dark shales and perhaps a little limestone, not seen in our section. The Portage rocks are exposed about Cressona and south of Schuylkill Haven	1,500–2,000
Hamilton group. Mostly shales and thin sandstones, fossiliferous, formed in the ocean. At the base is the *Marcellus black shale,* some 400 feet thick, sparingly fossiliferous, poorly exposed in the Schuylkill Valley. Above, the remainder of the Hamilton group is the *Mahantango formation,* very fossiliferous, gray, brown-weathering shale and some sandstones, seen in the neighborhood of Schuylkill Haven.	1,200
Onondaga group. Gray, marine limestone and locally shale, seen at only one place, a small abandoned quarry south of Schuylkill Haven.	50?
Oriskany group. Coarse sandstone and pebble beds with large fossil marine shells. Poorly exposed; seen between Adamsdale and Schuylkill Haven.	65?
Helderberg group. Limestone and limy shale, fossiliferous, marine, underlies region about Schuylkill Haven.	75+
SILURIAN SYSTEM	
*Bossardsville (Tonoloway) limestone.** Thin-bedded limestone; commonest fossils are ostracods. Beds believed to belong to this formation occur near Schuylkill Haven	Variable
Bloomsburg facies. Red beds, essentially barren, exposed at Post Clinton and to the north.	1,800
Clinton formation. Gray, hard sandstone, greenish shales and a few reddish or brown beds. Some of the sandstones rich in iron probably represent iron ore beds once mined at other parts of the State. The Clinton is well exposed north and south of Port Clinton. (N. B. Port Clinton is *not* the type locality for this formation. It takes its name from Clinton, N. Y.)	975
Tuscarora formation. Dominantly coarse, hard, whitish to light gray sandstone and conglomerate carrying the distinctive fossil *Arthrophysus alleghaniensis.* These strata are considered marine. They form the backbone of Kittatinny Mountain and are well exposed in the gap through it.	450

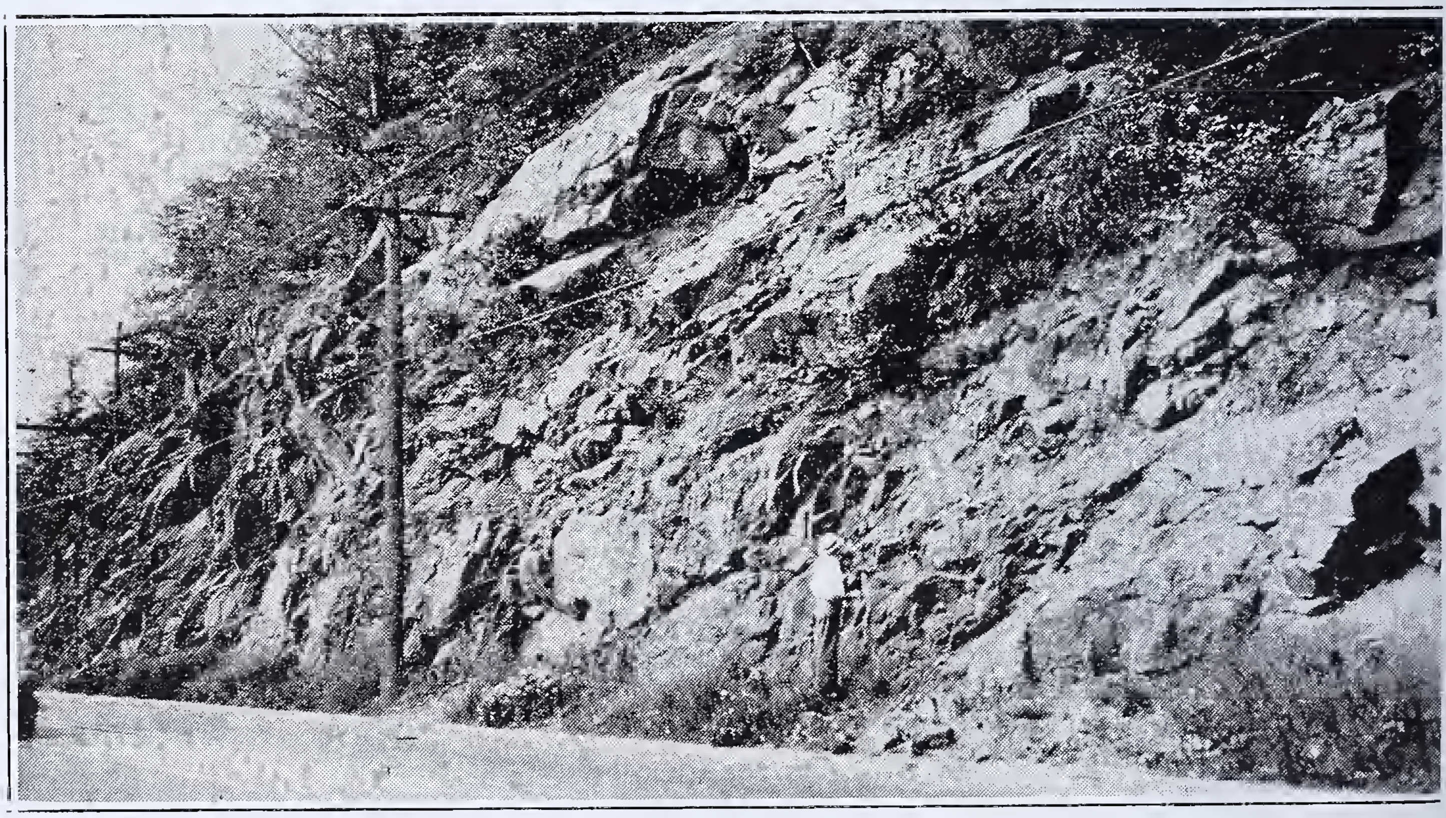
* Strictly speaking, the Devonian-Silurian line is now drawn slightly above the top of the Tonoloway in what is here included in the Helderberg group, but the question is quite technical, the exposures here are too poor to require such precise distinctions, and the literature cited in the list of references is largely of the older school which drew the boundary at the top of the Tonoloway or Bossardsville limestone.

ORDOVICIAN SYSTEM	*Thickness Feet*
Martinsburg formation. Dark shale with heavy sandstones at the top which, strictly speaking, probably should not all be included under this name. These show along the river above Hamburg. The shalier parts are fossiliferous at some places. In eastern Pennsylvania the Martinsburg is altered by pressure to slate, and in the southern exposures on the Schuylkill it is quite phyllitic. The basal part contains a varying amount of platy limestone	3,000?
Leesport limestone. Thin-bedded limestones at West Leesport, the type locality	50±
Beekmantown limestone. Massive, dolomitic limestone not exposed in our section, but underlies the southern part of the great valley between Leesport and Reading.	

As this bulletin is so written that one may conveniently start at the northern end of the excursion and work southward, and because in so doing, he will pass over successively older formations one after another, the following description of the several stratigraphic units is given in descending order, that is, from youngest to oldest.

PENNSYLVANIAN SYSTEM

The youngest rocks encountered in the region are those about Pottsville and are assigned to the Pennsylvanian system, commonly called the Coal Measures. Little is seen of these, and less need be said besides remarking that their basal part is called the *Pottsville formation.* This takes its name from the city of Pottsville, which is, therefore, the type locality for this formation. The rock consists of coarse sandstones and pebble beds or conglomerate, often strikingly white. Coal is present and plant fossils are common. The Pottsville is believed to have originated on land, perhaps largely as stream deposits.



Photograph by Geo. H. Ashley

Figure 4—Exposure of Pottsville formation on highway south of Pottsville.

MISSISSIPPIAN SYSTEM

Immediately beneath the Coal Measures or the Pennsylvanian system comes a succession of rocks which partake in part of the nature of the Pottsville and in part of the next older strata of the highest Devonian. These are the formations of the Mississippian system. Its upper part, immediately underneath the Pottsville conglomerate, consists of a thick succession, the *Mauch Chunk* red sandstones and shales. They are nearly devoid of fossil remains, although some peculiar foot tracks have been found in them in the region of Pottsville. These tracks are thought to have been made by animals distantly related to our present salamanders. Other fossils are practically unknown. The red beds are considered of continental (fresh-water) origin. These were particularly studied by the late Joseph Barrell who believed that they originated as outwash from near-by highlands, as fans or deltaic deposits.

The lower part of the Mississippian system in eastern Pennsylvania consists of what is called the *Pocono formation.* This is very much like the lower part of the Pennsylvanian, for it is composed of beds of coarse, gray sandstone and occasional conglomerates. Thin coal beds occur and have been mined in some places, but not economically, in Pennsylvania. The Pocono is fossiliferous. The known remains seem to be entirely those of plants similar to the later coal floras. Like the Pottsville, the Pocono beds were formed in fresh water. The details of the origin of this and other formations are given in the section on Historical Geology. The Pocono and Mauch Chunk formations are to be seen along the highway south from Pottsville. The Mauch Chunk crops out in the valley between Sharp and Second Mountains (the Pottsville forms Sharp Mountain), and the Pocono forms the northern of the two crests of Second Mountain.

DEVONIAN SYSTEM

Beginning in the valley between the two crests of Second Mountain and continuing south beyond the limits of Schuylkill Haven and reappearing again between Orwigsburg and Deer Lake, are beds assigned to the Devonian system. There are many sub-divisions to this system, which is widespread in Pennsylvania, and we shall mention several of the more important.

The highest beds of the Devonian are the *Catskill facies.* In the section on Historical Geology, mention is made of the origin of the Devonian strata and why we call the Catskill a facies rather than a group or formation as the other divisions of the system are designated. These beds are chiefly red, but among them there occur in various parts of the State, comparatively thick, greenish or gray sandstone units. In our section, one of these, the *Honesdale,* forms the southern crest of Second Mountain. It is lithologically very like the Pocono and has been sometimes confused with it. It is separated from the true Pocono of the northern crest by red beds in the intervening valley. These are the highest red strata of the Catskill. Beneath the Honesdale, that is, south of Second Mountain, the red beds resume

and continue south nearly to Cressona. The Catskill, like the red Mauch Chunk, is of continental origin, but the explanation of how it formed is somewhat different, as will be found under Historical Geology. Its fossils are few, consisting chiefly of plants, but a few remains of fishes have been discovered.

The Catskill red beds north of Cressona grade down into non-red, marine sandstones of the *Portage group.* The higher Portage beds are called the *Trimmers Rock sandstone.* Chiefly, they are flaggy, gray sandstones with locally also some greenish shale. Fossils are not at all rare, and are of marine animals, chiefly brachiopods, pelecypods and other mollusks which may be collected in the abandoned quarry at Cressona. The following fossils have been obtained from this formation in Schuylkill County:

Aulopora sp.
Crinoid columnals
Fenestella sp.
Bryozoa, indet.
Lingula sp.
Stropheodonta demissa
Chonetes vicinus
C. sp.
Rhipidomella vanuxemi
R. sp.
Schizophoria striatula
Camarotoechia congregata var. *parkheadensis?*
C. horsfordi?
C. sp.
Liorhynchus mesacostale
L. globuliforme
Tropidoleptus carinatus
Atrypa reticularis
Cyrtina hamiltonensis
C. sp.
"Spirifer" mesastrialis
"S." mucronatus var. *posterus*
"S." mesacostalis
Grammysia sp.
Sphenotus sp.
Nucula corbuliformis
N. bellistriata
N. sp.
Nuculites oblongatus?
Palaeoneilo plana
P. emarginata?
P. tenuistriata?
Leptodesma rogersi?
L. longispinum?
L. lichas
L. sociale
L. sp.
Modiella pygmaea
Actinodesma cf. *erectum*
Actinopteria sp.
Schizodus sp.
Modiomorpha concentrica
M. sp.
Cypricardella tenuistriata
C. sp.
Paracyclas lirata
P. sp.
Pterinopecten sp.
Pelecypoda, indet.
Pleurotomaria (Gyroma) capillaria
Platyceras sp.
Gastropod, indet.
Tentaculites spiculus
T. sp. nov.
Trilobite, indet.
Echinocaris (?) sp. nov.
Rhinocaris columbina
Ostracoderm fragments, indet.
Plantae, fragments

The remainder of the Portage group beneath the Trimmers Rock sandstone consists of shale, dominantly dark, and perhaps a little limestone. These beds are not exposed on our route, and for that reason they need only casual mention. Suffice it to say that the lowest Portage is usually either limestone or limy shale and is referred to as the *Tully.* It carries characteristic fossils, among them: *Lopholasma tullium, Hypothyridina venustula, "Spirifer" tullius, "S." pauliformis, Elytha fimbriata* and *Echinocoelia ambocoelioides.* Overlying the Tully is black shale, the *Burket* (formerly called "Genesee") which carries *Styliolina* and *Buchiola.* Between this and the base of the Trimmers Rock we usually find gray and perhaps some greenish shales correlated with the Harrell and Brallier to the west. They may con-

tain a sparse fauna similar to that referred to as the Naples fauna in New York and characterized by many small pelecypods and such cephalopods as *Bactrites, Manticoceras* and *Probeloceras.*

Under the Portage group comes the *Hamilton group* which occupies most of the Middle Devonian. It consists of two formations in this region, (above) the *Mahantango shale,* gray, non-fissile with scattered, locally thick sandstones, and (below) the *Marcellus shale*, black and fissile. The Mahantango formation is to be seen along the new highway west of Orwigsburg, but its best exposure is in the quarries at Deer Lake (Pinedale). Here it is highly fossiliferous. The following forms have been collected from this and near-by localities:

Aulopora sp.
Corals, indet.
Ancyrocrinus bulbosus
Crinoid columnals
Bryozoa, indet.
Discina?
Leptostrophia perplana
Stropheodonta sp.
Chonetes coronatus
C. scitulus
C. lepidus
Dalmanella cf. *lenticularis*
Liorhynchus sp.
Tropidoleptus carinatus
"Spirifer" mucronatus
"S." acuminatus
"S." audaculus
"S." cf. *audaculus*
Orthonota undulata
Grammysia arcuata
G. cf. *arcuata*
G. magna
G. cf. *nodocosta*
G. sp.
Nucula bellistriata
N. cf. *bellistriata*
N. lirata
N. corbuliformis
Nuculites triqueter
N. oblongatus
N. sp.
Palaeoneilo fecunda
P. emarginata
P. cf. *maxima*
P. constricta
P. sp.
Megamboria sp.
Pterinopecten sp.
Mytilarca (Plethomytilus) oviformis
Modiomorpha constricta
M. cf. *constricta*
Goniophora rugosa (?)
G. hamiltonensis
G. sp.
Cypricardella tenuistriata
Paracyclas elliptica
Schizodus sp.
Pelecypoda indet.
Pleurotomaria?
Bellerophon (Bucanopsis) leda
B. cf. *leda*
B. sp.
Hormotoma (Murchisonia) n. sp.
Loxonema cf. *bellona*
Platyceras (Orthonychia) conicum
Coleolus cf. *tenuicinctus*
Gastropod, indet.
Orthoceras subulatum
O. cf. *exile*
O. constrictum
O. sp.
Spiroceras crotalum
Bactrites cf. *aciculatus*
Trilobite, indet.

The Marcellus formation is not well exposed in the Schuylkill Valley, probably because its lithology causes it to weather readily and so form few outcrops. Along the new highway cuts west of Orwigsburg (east from Schuylkill Haven) and on the railroad north of Adamsdale the black, locally sandy, shale is exposed. At the latter place the following fossils have been collected:

Lingula sp.
Orbiculoidea minuta
Craniella cf. *hamiltoniae*
Inarticulate brachiopod, undet.
Camarotoechia dotis
Liorhynchus limitare
Actinopteria cf. *subdecussata*
A. muricata
Leptodesma cf. *rogersi*
Modiomorpha alta
Styliolina fissurella
Phyllocarid, indet

The remaining beds of the Middle Devonian are all but unknown in the Schuylkill Valley and are to be seen at only one place on the excursion. South of Schuylkill Haven on the Pennsylvania Railroad a small, abandoned quarry exposes the *Onondaga limestone.* Strictly speaking this is the *Selinsgrove limestone* as it is gray and non-cherty. The characteristic fossil is *Anoplotheca acutiplicata,* but other forms are known.

In the region about Schuylkill Haven the Lower Devonian is indifferently well exposed, but here is our only opportunity to study it. Beds of this age crop out on and near the Pennsylvania Railroad and on the new highway cut-off east from Schuylkill Haven. The *Oriskany group* consists entirely of coarse sandstone and pebble beds. These are fossiliferous. Among the characteristic, common forms are the brachiopods *"Spirifer" arenosus* and *"S." murchisoni.* Beneath the Oriskany comes the *Helderberg group.* This is a sequence of limestones and limy shales which is usually fossiliferous. It is thin and poorly exposed in our section, and nothing further need be said of it.

SILURIAN SYSTEM

The next older system below the Devonian is abundantly and well exposed in the Schuylkill Valley. It is divisible into several parts, the character and succession of which have been worked out chiefly through the efforts of C. K. and F. M. Swartz. The beds commonly assigned to the top of the Silurian are, like the Helderberg group of the lowest Devonian, limestones and shales. The older usage has been to draw the Silurian-Devonian boundary at the top of the thin-bedded *Tonoloway* or *Bossardville limestone.* (These names appear to be synonymous, the former in use in central, the latter in eastern Pennsylvania.) The most recent developments draw the line a little higher, but the matter is of small significance in the present discussion. Beneath the Helderberg in the Schuylkill Valley these higher Silurian strata are known. They often carry large numbers of ostracods.

The most striking element of the Silurian system, as we shall see it on the tour, is a great mass of red beds called the *Bloomsburg facies* and analogous in origin to the Catskill facies of the Devonian. These are red sandstones and shales with here and there a peculiar, bright green shale parting. Fossils are very few, but within a few miles of the Schuylkill Valley, plant remains have been discovered. The Bloomsburg is of continental or fresh-water origin. Under these red beds, and grading up into them, comes the *Clinton formation.* In the extreme eastern part of the State, all of the Silurian beds beneath the Bloomsburg are known as the *Shawangunk formation.* As this is traced westward, it resolves itself into the Clinton above and the Tuscarora below. The Clinton is chiefly sandstone, gray, hard, resistant. With these sands occur also greenish shales, and a few red or brown beds. Some of the red units are high in iron oxide content. It is supposed that they represent the iron ores of this age found in central Pennsylvania and extensively exploited half a century or more ago.

The *Tuscarora formation* is supposed to be sea-formed. It consists of massive beds of light gray to whitish sandstones and much conglomerate. These beds are best seen in the water gap above Hamburg where they pass northward into the Clinton and then the Bloomsburg. The Clinton rises again north of Port Clinton (*not* the type locality) in a large anticline which has been faulted, according to the account by Swartz and Swartz. The Bloomsburg is well exposed about Port Clinton and in the region south of Schuylkill Haven where it comes up in a long, narrow anticline.

ORODOVICIAN SYSTEM

The Ordovician system is the lowest which we shall observe on this trip. It consists in brief of two elements, shale above and limestone below, both very thick and underlying wide belts of country. The shaly, Upper Ordovician is the *Martinsburg formation*. In more eastern sections, most of the shale has been metamorphosed to slate, and in fact, in our southern exposures of these beds, they are more or less slaty or phyllitic. The upper part of the Martinsburg becomes sandy, and very massive beds show along the river north of Hamburg to the Water Gap. Perhaps some of these are even younger than the true Martinsburg. In northeastern Berks County these or closely related beds carry a Pulaski fauna. The following list is quoted from Stose:

Rafinesquina, small, aff. *camerata*
Rafinesquina cf. *alternistriata*
Rafinesquina aff. *ulrichi*
Strophomena n. sp. (like *S. sinuata* coarsely striated)
Sowerbyella aff. *sericea*
Dalmanella aff. *multisecta*
Dalmanella sp.
Zygospira modesta
Ctenodonta cf. *levata*
Other small pelecypods
Sinuites aff. *cancellatus*
Tetranota sp.
Liospira aff. *progne*
Lophospira aff. *obliqua*
Lepidocoleus jamesi
Calymene sp.
Proetus aff. *parvimusculus*
Ctenobolbina cf. *ciliata*

In the same region the black shales beneath the sandstones carry Eden fossils, including such forms as *Sowerbyella* and *Cryptolithus.*

The basal Martinsburg becomes limy. Platy limestones and limestone breccias appear south of Shoemakersville and may make up so large a proportion of the rock that locally they have been quarried and burned for lime (Figure 5).

Under the Martinsburg at West Leesport is the platy *Leesport limestone.* It is barren of fossils, and probably has a rather local distribution and is of relatively little significance. At this type locality it has been much disturbed, so that it is not a satisfactory section to study, although we shall visit it. It overlies the *Beekmantown limestone,* which is a very massive, dolomitic, thick formation, almost barren of fossils, and not exposed in our section. Probably all of the Ordovician formations are marine throughout, although local red beds in the Martinsburg suggest incursions of continental conditions.

Photograph by Bradford Willard

Figure 5—Platy limestone in lower Martinsburg, exposed in quarry east of the Schuylkill, Berks County.

STRUCTURAL GEOLOGY

Structural geology has to do with the "lay" of the rocks. We have noted that those of the Schuylkill Valley seldom are found lying flat. The beds are tilted at all angles. Where they have been bent up into an arch, the structure is called an *anticline;* where they are sagged down, a *syncline.* Pressure, presumably from the south and southeast, squeezed the thick deposit of rocks of the several systems into a series of large and small folds. The strong, heavy rocks, such as the Tuscarora and Pottsville, bent into great folds, and the weaker beds, the Bloomsburg and shaly part of the Martinsburg for instance, were crushed and sheared. Where the pressure was too great for the strength of the rocks, the beds fractured; one part slid over another. Such a dislocation is called a *fault.*

The mountainous regions below Pottsville exhibits many folds, particularly along the highway in the vicinity of Port Clinton. Small folds are well illustrated in the Silurian in the new highway cut-off west of Orwigsburg. Here, too, small faults may be seen, and a large fault involving the Clinton beds is recognized by Swartz and Swartz north of Port Clinton. The Ordovician-Silurian contact at the gap in Kittatinny Mountain is an interesting and puzzling structure over which geological opinion is divided. At this point the nearly horizontal Martinsburg sandstone and shale butt against the nearly vertical Tuscarora sandstone and conglomerate (Figure 6). One interpretation is that the Martinsburg strata were folded and eroded low (peneplaned),

leaving their raw edges upturned. On these the Tuscarora was laid down in what is called an unconformity, that is, the beds on opposite sides of the contact were not mutually parallel. Finally, the whole thing was upturned into its present position. Another explanation is that the Martinsburg and Tuscarora were originally deposited in conformity, meaning that the beds on opposite sides of the contact were parallel. In a subsequent interval of squeezing, the weaker Martinsburg strata were doubled up beneath the massive Tuscarora into the present relationship.

HISTORICAL GEOLOGY

The story of the region begins with the Ordovician period. At that time a vast, inland sea occupied much of North America, spreading westward many hundreds of miles from the region of Pennsylvania. Along its eastern coast was a land mass, a remnant of which may be represented in South Mountain and the hills at Reading. Into the sea were washed gravel, sand and mud from the land when that region was high and its streams were busy eroding its surface. When, however, the land was worn low and those streams were sluggish, as sometimes happened, little mud or sand entered the ocean, and lime ooze was precipitated on the bottom. The ooze hardened to limestone.

The Ordovician period saw the deposition of much limestone, the Beekmantown and overlying local Leesport formations. About the close of Beekmantown time, mud commenced to enter the sea from the ancient land to the east, and there was a gradual change from lime to muddy lime to mud. This accounts for the changes noted in the lower part of the Martinsburg formation in which platy limestone and shale gradually yield place to shale. Toward the close of Martinsburg time, a great influx of sand built up those massive, Upper Ordovician sandstones seen north of Hamburg. If we accept the first hypothesis advanced in the section on Structural Geology for the explanation of the Ordovician-Silurian relations as exposed at Schuylkill Gap, we must allow an interval of mountain building or strata squeezing at the close of the Ordovician. Such a disturbance is known in parts of eastern North America and is called the *Taconic disturbance* from the resulting Taconic Mountains of eastern Massachusetts and New York. It seems possible to those who advocate this theory, that this disturbance extended its influence into eastern Pennsylvania. It must be admitted, however, that there is little or no evidence for its projection much farther west than the Susquehanna Valley.

The Silurian period was one during which a vast amount of sand, pebbles and mud was swept seaward and deposited as the pebbly and sandy Tuscarora and Clinton formations. One may ask, and with good reason, why, if all this material was carried into the sea, didn't it fill up? As a matter of fact, it did, but very gradually. Another factor, or process, too complex to discuss here, was busy counteracting the influx of sediments. As these piled up on the ocean floor, that same floor tended to sink, keeping at times nearly even pace with the increase of thickness of sand and mud. Eventually, in Silurian

Photograph by Geo. H. Ashley

Figure 6—Ordovician-Silurian contact on Pennsylvania Railroad, west side Schuylkill Gap. Nearly flat-lying Martinsburg shale and sandstone strata at left; almost vertical Tuscarora sandstone and conglomerate at right.

times, the sea did fill, though only temporarily. The red Bloomsburg shale and sandstone is of fresh-water origin and represents a mass of mud and sand which accumulated above sea level after the sea bottom had been built up above tide. Though almost barren, these beds are known to carry remains of plants, locally in sufficient quantities to have produced films of coal. If one had time to follow the Bloomsburg red beds northwestward into the middle Susquehanna Valley, he would find that they are much thinner and that the red shale and sandstone are passing over and mingling with brown sands and shales with marine fossil shells. Thus, the red beds represent fresh-water sedimentation, while at the same time salt-water beds formed in the as yet unfilled sea farther away from the ancient land mass, the source of supply of sediment. It is for this reason that we refer to the Bloomsburg red beds (and the Catskill, too, as we shall see) as a *facies*. They are the continental facies, and the contemporaneously sea-formed beds are the marine facies.

Before the end of Silurian time, the sea came back, as is known from the relatively thin deposit of marine limestone, the Tonoloway or Bossardsville, which continues practically unbroken into the Helderberg group of early Devonian age. During the Devonian we might have witnessed, had we been privileged to be present, a process very much like that of the Silurian. There was a long interval during which marine strata represented by the Helderberg, Oriskany, Onondaga, Hamilton and Portage groups were deposited. Then, as in the counter-

part of the Silurian, the sea filled above tide level, and the red beds of the Catskill were deposited. Here again, as with the Bloomsburg, if we could follow these continental beds far enough away from the old source of sediment, we should find them changing gradually into marine strata with sea shells instead of the occasional plant fossils or mats of stems characteristic of the Catskill facies.

One might suppose from observing the Bloomsburg and Catskill facies that fresh-water sediments are usually red. This is not always true, but the color is presumptive evidence, though we may have non-red fresh-water beds. The red color is due to the presence of ferric iron (iron rust). It is found in beds with very few plant remains. The Pocono formation (of early Mississippian age) above the red Catskill is gray. It, too, formed in a fresh-water environment, but it contains abundant plant remains. Plants contain much carbon, and carbon has a greater affinity for oxygen than has iron. Consequently, even though the Pocono formation carries proportionately as much iron as does the Catskill, its more abundant plant remains have tended to hold some of the oxygen which would have turned the iron to red ferric oxide. The iron in the Pocono is thus in a ferrous state and is not red. The Mauch Chunk red beds, which have almost no fossils of any sort, seem to be a reversion to Bloomsburg and Catskill condition. This is only partly true. The overlying Pennsylvanian Coal Measures are Pocono-like in that they are fresh-water formed and non-red.

After the deposition of the Coal Measures, nothing is known to have been added to the strata in this part of Pennsylvania. The sea was filled and never returned, and the old land to the east largely disappeared. But, at the close of the Pennsylvanian time or slightly later there came one of those great "upheavals of nature" which geologists refer to as revolution. This was no sudden convulsion, but a slow and gradual compression from the east or southeast of the rocky beds, bending, crushing, breaking them to form the structures we see today. Because the Appalachian Mountains were the result of this activity, we call it the *Appalachian Revolution.*

The Appalachian Revolution lasted a long time. Next the folded rocks were subjected to erosion, and gradually the eastward-flowing rivers reduced the land surface to low level. This stage is referred to as the *Schooley peneplane.* When it had been attained the streams flowed indifferently over the hard and soft rocks alike. Subsequent to the development of the Schooley peneplane, the land was again raised or up-tilted. Streams then rejuvenated, resumed their downward cutting. The more rapid, powerful courses maintained their established channels across hard and soft beds alike, but the weaker streams, unable to keep pace with the rising land surface and hold their courses across the hard rock bands, adapted themselves to softer rock bands, cutting them down and so etching out the harder strips. With the major streams holding their courses and plowing cross-grain over hard and soft rock bands alike, gaps were cut by them in those harder bands which the weaker, tributary streams now etched out into parallel ridges. Thus, in time, this part of the State

became broad valleys with small streams flowing longitudinally along them, and parallel ridges across which the larger streams cut in water gaps. The present level crests of all the mountains of this region are thought to reflect the peneplane that once existed and was uplifted and dissected during the development of the present topography.

DETAILED ITINERARY

The route of this excursion follows the Schuylkill Valley, keeping chiefly to the east side of the river, from Pottsville south through Hamburg and Leesport. Except for short detours to visit near-by localities, the route is along U. S. Highway 122. Mileages given are from the starting point on Route 122 at the south edge of the city of Pottsville. A copy of a reliable road map, such as that published by the Pennsylvania Department of Highways, will be found useful in keeping track of the distances.

Miles

0.0 The trip starts on Route 122 at the south edge of Pottsville at the Pottsville-Mount Carbon line. Pottsville is the type region for the Pottsville formation (largely conglomerate) which is the lowest major division of the Coal Measures. At this place, road cuts along the west side of the highway expose the Pottsville conglomerate and sandstone. These are the hard rocks that support Sharp Mountain through which the river has cut a water gap immediately south of the city of Pottsville. Proceeding south from the starting point, additional exposures of the Pottsville conglomerate are seen. Ordinarily this is a light-gray to white rock, but here it is discolored with smoke and soot. Thin bands of red rock appear among the more typical Pottsville strata.

0.2 Cuts along the west side of the highway expose the Mauch Chunk red sandstone and shale. These beds belong to the upper part of the Mississippian system which underlies the Coal Measures. The beds stand nearly perpendicular and are exposed most of the way south to the underpass beneath the Reading Railway.

0.4 After crossing the Schuylkill, the road continues south along the east bank, and the Mauch Chunk red beds are still more exposed in a series of cuts along the railroad, south to the north flank of Second Mountain.

1.0 At this point the river has cut a water gap through Second Mountain. Note particularly that this mountain is a double crested ridge. Each crest is supported by a massive, gray sandstone and conglomerate, but the small valley between is underlain by soft, red shale and sandstone. The beds all stand nearly vertical or dip very steeply north. As the highway passes the first of the crests of Second Mountain, a long cut on the railroad east of the highway exposes the rock that supports this crest. It is the Pocono sandstone and conglomerate of early Mississippian age. It underlies the Mauch Chunk red beds just observed to the north, and overlies the Catskill red beds in the valley between the two crests of this ridge. The beds of the Pocono are hard and resistant. They dip very steeply. This is because long after being laid down, they were subjected to great squeezing, the pressure coming from the south and southeast. As the beds were folded, they were more or less crushed. Note how they are broken by joints, a series of cracks vertical to the bedding surfaces. Near the north end of this cut is a dark shale interbedded with the sandstones. It suggests poor coal; and, in fact, coal is found in this formation at certain localities, but is not economically mined in Pennsylvania. The contact of the Pocono with the overlying red Mauch Chunk is exposed at the north end of this cut.

Miles

1.4 The road here crosses the valley between the two crests of Second Mountain. Most of the cuts expose only talus of loose blocks which have slid or fallen from the crests, but some of this float rock is red, and to the west across the river on the Reading Railway may be seen more red beds in place. These belong to the Catskill and are among the highest of its red strata. They are the relatively soft, non-resistant beds that separate the two mountain crests here. Cuts in the valley between the crests at 1.7 miles show a little of the dark red Catskill sandstone and shale.

1.8 At this point the road forks. We continue south on U. S. Route 122. To the east, a side road passes under the Pennsylvania Railroad track and then up-grade. Cuts on this side road are in dark-gray sandstone very similar to the Pocono which we saw in the northern crest of Second Mountain, but are older and separated from the Pocono by the red beds in the intervening valley. These gray strata are part of the Honesdale sandstone which is interbedded with the Catskill red strata. It has often been confused with the Pocono which it so closely resembles, but is considerably older and belongs in the Devonian system, whereas, it will be remembered, the Pocono is of Mississippian age.

2.4 Looking west across the river, railroad cuts expose the Catskill red beds which underlie the Honesdale of the southern crest of Second Mountain. These are similar, though slightly older than those in the valley between the crests. It is now apparent that the Honesdale comes between red beds of Catskill facies, and is, therefore, distinct from the younger Pocono with which it has been sometimes confused. To the southwest the higher ground marks the position of the Portage sandstones which we shall see presently.

2.8 Cuts along the Pennsylvania Railroad to the east fail to show the contact between the Catskill red beds and older, non-red Portage sandstones (Trimmers Rock), but the latter is now exposed abundantly.

3.1 Right (west) on hard road across the Schuylkill and the Reading Railway towards Cressona. After crossing the railroad, make a U-turn and park in space south of the concrete highway. This stop is made for the purpose of studying an exposure of the Portage rocks in an abandoned quarry on the north of the road. These vertical beds are in the Trimmers Rock sandstone which is the principal stratigraphic unit of the Portage of the Upper Devonian formations in this part of Pennsylvania. A nearly complete sequence of the sandstone is to be seen on the Reading Railway north from here. At this point in the abandoned quarry the beds carry some shale and are fairly fossiliferous with remains of sea shells (principally brachiopods). These beds were laid down in shallow sea water. That it was part of the sea is attested by the kind of fossils present. That it was shallow is deduced from the fact that some of the beds show ripple marks produced by currents and tides in shallow water, and others are cracked where they were exposed as mud, dried, and were buried by later sediments. Jointing is also present. Return across the railroad and river to Route 122, and thence south toward Schuylkill Haven.

3.7 At the intersection of Route 122 and the road to Cressona, a large cut to the east under the Lehigh Valley Railroad bridge gives us an additional exposure of the Portage sandstones. Concealed here, but exposed at many localities, are lower Portage shales (See Guide Books, Bulletins G8 and G12).

6.1 The road crosses several formations through Schuylkill Haven (see map Plate 1), but these are concealed. East of Schuylkill Haven, at the intersection of the old highway (to Orwigsburg) and the new route south, cuts along the concrete expose beds of Hamilton shale. We have thus passed from the Upper Devonian down into the Middle Devonian.

6.5 Turn sharp right (south) on hard-surfaced road to Adamsdale.

Miles

7.2 Adamsdale; right (west) toward Schuylkill Haven. As the road crosses the Reading Railway (7.6 miles) cuts along the track expose the Marcellus black shale which is at the base of the Hamilton group of Middle Devonian formations.

8.4 Cuts along the east side of the road expose rather heavy sandstones belonging to the Hamilton.

8.5 Quarry (Delago's) east of the road. This quarry has been opened in beds of the Helderberg limestone and is worked for crushed stone. They are of earliest Devonian age. In the south wall of the quarry the limestone is overlain by some thin shale, and then the Oriskany sandstone, also of the Lower Devonian. This is a great gas-producing sand of our northwest, and is the formation worked for glass sand in central Pennsylvania. Here it is quite pebbly. The contact with the underlying beds is sharp and interesting in that it shows how suddenly the kind of rock may change (figure 7). From this quarry the route is retraced east toward Adamsdale.

Photograph by Bradford Willard

Figure 7—Contact (at hammer) between Helderberg limestone below and Oriskany sandstone above, Delago quarry, near Schuylkill Haven.

8.6 Immediately south from Delago's quarry a path leads up the hillside to the railroad. Those who are interested will be repaid by climbing this slope to see the section along the railroad and on the hill above it. The northernmost part of the railroad cut above and a little north Delago's quarry exposes red beds that belong to the Bloomsburg facies of the Silurian system. They dip south and are overlain by shale and limestone, in part the same beds seen in the quarry. Some of these strata are fossiliferous, chiefly with many ostracods. The Oriskany sandstone is not well exposed on the track, but above it on the hill slope there is an abandoned quarry in this formation. Here the sandstone and conglomerate are well exposed. Walking south along the hill slope at the level of the quarry in the Oriskany, and keeping above the cleared ground, another small quarry is presently encountered. This one is in limestone. It is the Onondaga limestone which marks the base of the Middle Devonian. Its contacts are hidden, but it probably lies directly on the Oriskany sandstone and is overlain (to the south) by the Marcellus black shale and then sandstones of Hamilton age seen in the next railroad cut to the east. Returning from here to the road, the route is retraced east to Adamsdale and thence north, back to Route 122, on which we turn east again (10.5 miles).

Miles

10.8– A long cut up-grade at this point exposes most of the Middle and Upper
11.2 Silurian formations up to the basal Devonian, starting from the north end. In the north end is the Bloomsburg red shale (seen also on the railroad above Delago's quarry). The red beds pass upward into non-red shales and limestones for about 100 feet of thickness. The highest limestones carry a few poorly preserved fossils. At the top (south end of cut) cherty beds probably belong to the Oriskany or to the highest Helderberg strata. The shaly beds above the Bloomsburg have been more or less crumpled into a series of small "waves," some of which have broken in little faults which show clearly the nature of such structures with the beds on opposite sides of the surface of fracture displaced so that they no longer "match up."

11.6– Down-grade, more cuts along both sides of the highway expose additional
11.8 strata of Middle Devonian age. Between here and the last cut to the north, float rock of the Oriskany sandstone is seen. The dark shale is assigned to the Marcellus or slightly younger Mahantango formation of the Hamilton.

11.9 One-tenth mile east of the road is an abandoned sandstone quarry in the Mahantango sandstone and shale. Fossils are scarce and the lithologic character of the beds indicates that they are probably low in the Manhantango, perhaps nearly in the top of the Marcellus formation which is not well known in this area. The quarry exposes some remarkably fine joint faces.

13.4 Cuts along the road are in shales of the Hamilton group.

14.2 The old road from Orwigsburg rejoins the new. Cuts here and southward afford intermittent, though poor, exposures of the higher Hamilton beds.

15.4 Deer Lake; large cuts and quarries west of the road. The beds are of about middle Hamilton age (Middle Devonian) and are very fossiliferous. This is one of the best collecting grounds for fossils of the Mahantango formation in this part of Pennsylvania.

16.3 Continue south, up-grade from Deer Lake, past the intersection with State Highway 895 to Auburn. At the top of the grade a splendid view is had of Schuylkill Gap in Kittatinny Mountain to the south. Continue on downgrade. Cuts in Bloomsburg red shale are plentiful.

17.1 Quarry, west side of highway, exposes the red Bloomsburg shale of the Silurian system. This is a particularly good place at which to observe the thin, bright green, shale partings among the red beds, a feature quite characteristic of this facies. The strata have been sheared perpendicular to the bedding. Continuing down-grade, at 17.2 miles a road east leads to Hawk Mountain Sanctuary. Bird lovers will be repaid by a trip to this interesting place, and at the same time the geology and physiography of the mountain are worth the climb. Most of the distance is covered by car on the secondary road across Kittatinny Mountain from Drehersville to Eckville.

17.6 An abandoned quarry east of the road after crossing the Little Schuylkill exposes more of the Bloomsburg red beds which make up most of the Upper Silurian in this section. Southward, a splendid Silurian section is to be seen. A description has been published in detail by Swartz and Swartz (see list of references). They record some 1,800 feet of the red beds in the region of Port Clinton.

18.1 Entering the upper gap above Port Clinton, the older, sandy Silurian (Clinton) beds rise to the surface from beneath the Bloomsburg, and then descend again in a long section on the highway near the covered bridge west across the stream.

18.9 Passing through Port Clinton, abundant exposures of the red Bloomsburg shales are again encountered.

19.6 South of Port Clinton, the Clinton formation again comes up to the surface.

Miles

19.9 The Clinton sandstones pass downward into the Tuscarora gray sandstones and conglomerates which form the massive ledges of the main ridge of Kittatinny Mountain at the Schuylkill water gap.

20.0 The parking space, right, at the turn of the road as one leaves the gap, affords a chance to pause and observe the geology at this point. Across the Schuylkill on the railroad tracks, cuts expose what is perhaps one of the most spectacular geological phenomena in the State, the contact between the nearly vertical Tuscarora sandstone of the Lower Silurian on the north, and the nearly horizontal shales and sandstones of the Martinsburg (Upper Ordovician) on the south. It is still an unsolved puzzle as to precisely how these relations were brought about. Continue southward on Route 122.

20.3–20.5 The road turns east and follows a bend in the river, cutting back into beds probably in the lower part of the Clinton, and then turns south again to recross the Tuscarora formation. These beds are well exposed along the highway at the county line and beyond in several large cuts.

20.6 At this point opposite the old dam in the river, the Silurian-Ordovician contact is crossed. The precise contact is hidden, but the relation of the vertical Tuscarora and nearly horizontal Martinsburg strata is evident and is precisely the same as noted across the river at the entrance to the gap. A few feet north of the contact, greenish beds of the Tuscarora carry the fossil *Arthrophycus* (Figure 8).

Photograph by Geo. H. Ashley

Figure 8—*Arthrophycus* bed near base of Tuscarora formation, highway cut, east side of the Schuylkill below gap in Kittatinny Mountain.

21.0 Continuing south through 22.5 miles, many cuts and some abandoned quarries expose the Martinsburg formation of Upper Ordovician age. Strictly speaking, these heavy sandstones are not at all typical of most of the Martinsburg which is usually a shale, except in eastern Pennsylvania, where it has been metamorphosed into slate (in the Slate Belt). It is not im-

probable that these sandstones are somewhat younger than the true Martinsburg. The section continues south through Hamburg.

22.8 In Hamburg, and southward, Martinsburg sandstones are exposed occasionally.

23.8 Characteristic shaly Martinsburg is exposed in small cuts here and southward in new highway cuts up-grade at 24.8 miles.

25.3 A good view is here obtained southward across the lowlands underlain by shale, near us, and limestone, beyond away to the hills about Reading. Those hills are composed in large part of Cambrian and pre-Cambrian crystalline rocks. These are very old rocks, among the most ancient in the State, and underlie all that we have observed in this excursion. The section is concealed through Shoemakersville, but the rolling topography indicates that the underlying rock is still the Martinsburg shale (Figure 2).

28.1 East of the highway is the abandoned plant of the Glen-Gery brick works, which exploited the Martinsburg shale.

29.4 South of Mohrsport, cuts on the road east across the railroad (Route 122 lies west of the railroad) show the Martinsburg with interbedded, platy limestone in abundance. This sort of limestone is encountered widely in the Martinsburg in parts of Pennsylvania. (See R. L. Miller's accounts in list of references.)

30.0–30.5 New road cuts expose interbedded platy limestone in the shale in the lower part of the Martinsburg.

31.2 Leesport. Turn right on State Route 383 to West Leesport, crossing the Pennsylvania Railroad and the Schuylkill.

31.6 The cut on the railroad is the type locality for the Leesport limestone, a peculiar, thin-bedded or platy limestone of rather local distribution found at the base of the Martinsburg shale and separating it from the underlying, massive, dolomitic Beekmantown limestone. The section shows the phyllitic shales of the lower part of the Martinsburg above the Leesport limestone. Faulting, crushing and folding have disturbed the sequence somewhat. From here, turn about and return to Route 122 (32.0 miles) and continue south toward Reading. Bulletin G 15 should be consulted for the region about the city.

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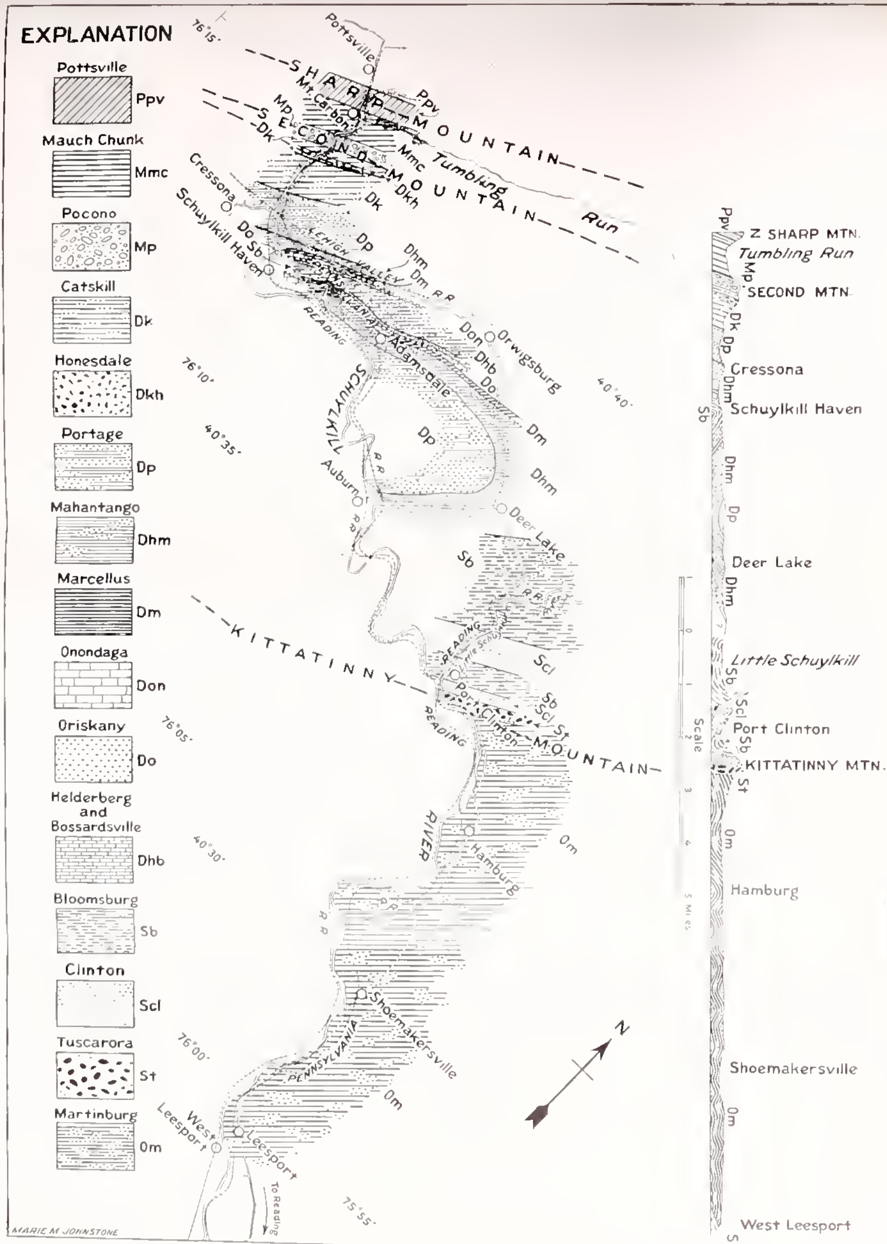

Geologic sketch map and north-south section along the route between Pottsville and Leesport.